

Hedonic contrast and the short-term stimulation of appetite

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Hedonic contrast stimulates appetite

Hedonic contrast and the short-term stimulation of appetite.

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Short title: Hedonic contrast stimulates appetite

Abstract

Hedonic contrast describes how liking for one item is influenced by the recent experience of other items which differ in hedonic valence. In the context of food stimuli, there is abundant evidence that hedonic contrast alters liking, but limited information on its impact on intake, and the aim here was to further clarify how hedonic impact modifies intake. Participants (96 female volunteers) rated and consumed ad libitum a sequence of four bowls of a snack (potato crisps) in one of three conditions. In the Palatable (salted crisps) and Bland (unsalted crisps) conditions, all four bowls were the same. In the Contrast condition participants alternated between salted and unsalted crisps. In total, significantly more was consumed in the Palatable ($35.0 \pm 2.6\text{g}$) than Bland ($26.6 \pm 2.4\text{g}$) condition, but most was consumed in the Contrast condition ($37.0 \pm 1.6\text{g}$). The impact of hedonic contrast was seen in the third serving, where those in the Contrast condition consumed the most of any serving, and significantly more than in Palatable or Bland conditions, and at the final serving, when those in the Contrast condition consumed significantly less than in Bland or Palatable conditions. Rated liking for the foods showed a similar pattern, with liking decreasing across servings in Palatable and Bland conditions. However, liking was influenced by the preceding serving in the Contrast condition, and the change in liking produced by contrast predicted subsequent intake. Overall, these data provide clear evidence that hedonic contrast can influence consumption, with intake driven by this adjusted liking.

Keywords:

Hedonic contrast; liking; palatability; food intake

1.0 Introduction

The impact of hedonics, i.e. how much we like the food that is being consumed, has long been of interest in appetite research and is a central feature of many important theoretical models of appetite control. Firstly, there is the idea that flavour hedonics act as a key driver of short-term intake, founded in classic ideas and studies (see Yeomans, Blundell, & Leshem, 2004). Secondly, specific liking for the consumed item decreases during ingestion, defined as sensory-specific satiety (SSS: Rolls, Rolls, Rowe, & Sweeney, 1981). Finally, the idea of negative gustatory alliesthesia suggests that liking in general decreases with ingestion, but here the idea is that the expression of liking is one consequence of current homeostatic appetitive state: that is, liking is increased when we are hungry, and decreased when sated (e.g. Cabanac, 1979). Alliesthesia also contrasts with a newer concept of “hedonic hunger”, where people seek pleasure from eating independently from homeostatic controls (Lowe & Butryn, 2007).

However, in all four of these theoretical approaches, there is either an implicit or explicit idea that liking for food results from the specific sensory characteristics of the ingested item. That basic premise is challenged by the idea of hedonic contrast, where how much we like one product is modified by our evaluations of other products evaluated at the same time (Sherif, Taub, & Hovland, 1958). In relation to ingestion, to date hedonic contrast has been examined extensively at a sensory level, with evidence for hedonic contrast in many studies using food and drink stimuli (see Zellner, Allen, Henley, & Parker, 2006). For example, previous studies have evidenced contrast effects on liking with fruit juices (Zellner, Rohm, Bassetti, & Parker, 2003) and with food-related odours (Stevenson, Tomiczek, & Oaten, 2007). But the impact of hedonic contrast on actual ingestion remains less explored.

Moreover, whether any effects of hedonic contrast on ingestion require an additional explanatory construct for short-term appetite control, or can be explained adequately through the interaction of palatability and SSS effects, is untested. The present study was therefore designed to test the impact of hedonic contrast on food intake in a snack context to try and redress these shortcomings in what we know.

Numerous laboratory-based studies with human volunteers have demonstrated that manipulation of liking for a product alters intake (see Sorensen, Moller, Flint, Martens, & Raben, 2003; Yeomans, et al., 2004 for reviews). The experience of a liked food increases the ratings of hunger (Yeomans, 1996), and that increase in overall appetite drives additional ingestion. The effects of palatability are quantifiable: intake increases as a linear function of overall rated liking for the ingested food (Kissileff, 1986; Yeomans, 1998). Effects of palatability on ingestion have also been seen outside the laboratory: analysis of detailed diary intake data found that palatability predicted intake (De Castro, Bellisle, & Dalix, 2000; de Castro, Bellisle, Dalix, & Pearcey, 2000), and did so even though the range of palatability people self-selected was limited. Notably, effects of palatability in those studies were additive to effects of hunger, contrary to the predictions of alliesthesia and supporting the broader concept of hedonic hunger. Thus, at a behavioural level there is abundant evidence for a key role for palatability as a short-term driver of ingestion, and this is often cited as a driver of overconsumption leading to obesity (Johnson & Wardle, 2014).

As food is ingested, liking for the ingested food decreases, but liking for other uneaten items remains unaltered (see Hetherington & Havermans, 2013; Vickers, 2017 for reviews), the defining feature of SSS. It is well known that more is consumed when a variety of foods are

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available than when only one food can be eaten, an effect first demonstrated in classic studies with animals (Le Magnen, 1960), and then replicated many times in human studies (Raynor & Epstein, 2001; Remick, Polivy, & Pliner, 2009; Rolls, Rowe, et al., 1981). SSS provides an elegant explanation for the effects of variety: as the consumer switches between different foods, the effects of SSS are ameliorated.

The combination of SSS and palatability effects offer a clear model for how liking may influence short-term food intake. But both assume that liking for foods are a direct consequence of the specific sensed sensory characteristics of that food. Hedonic contrast challenges that assumption, since it suggests that liking is modified by the context in which the product is experienced in a very specific way. The concept of hedonic contrast is far from new: contrast effects in terms of sensory perception date back to some of the earliest sensory studies (Wundt, 1896), while the idea of hedonic contrast can be dated back to observations in cuisine that greater pleasure is experienced when a food has a source of lesser pleasure to compare it with (Beebe-Center, 1932). There are now numerous studies reporting hedonic contrast effects with orosensory stimuli (see Zellner, 2007 for review). For example, participants rated a test drink as more palatable if rated after exposure to a less liked drink (Sakai, Kataoka, & Imada, 2001). Likewise, when a plain-flavoured product was experienced after a flavoured version, a negative contrast effect was found (i.e. liking for the plain product was reduced), whereas when presented in the reverse sequence, a flavoured product was liked more if it followed a plain product (Mazur, Drabek, & Goldman, 2018).

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To date two studies have specifically examined whether hedonic contrast altered evaluations of foods presented in multi-course meals. In the first (Lahne & Zellner, 2015), participants evaluated liking for the main course of a meal (pasta) following consumption of a first course (starter, bruschetta) which was manipulated to be rated as more or less pleasant. There was clear evidence for hedonic contrast: the main course was rated as significantly less pleasant tasting when served after the more pleasant starter. A follow-up study then tested whether this hedonic contrast was still seen when both served courses were from the same or different cuisine (Lahne, Pepino, & Zellner, 2017): here the evidence suggested larger contrasts when the two served foods were from the same than from different cuisines even though foods were matched on absolute liking ratings, suggesting that hedonic contrast is not simply down to liking per se, but includes higher level concepts of “sameness”. However, neither study tested whether the altered hedonic evaluation through contrast modified how much was consumed.

To our knowledge, the only study to date that measured the impact of hedonic contrast on intake did so in the context of olfactory and visual stimuli (Stevenson, et al., 2007). In two studies, participants smelled a set of eight food-related odours which were either all rated as pleasant or unpleasant, before smelling and consuming a target drink. Prior exposure to the more pleasant odours resulted in lower liking and intake of that drink compared to pre-exposure to the unpleasant stimuli. Viewing and rating pleasant or unpleasant pictures did not have the same effect. These results confirm the hedonic contrast effect, but evidenced by orthonasal experience of food-related odours. The aim of the present study was to extend this to explore hedonic contrast progressively across a snack test where the contrast

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was with the valance of the preceding course to test whether these effects continue beyond the initial experience of a food.

In designing the present study to examine hedonic contrast effects across multiple servings, we were mindful that since absolute intake would be affected by liking, it was important to control for potential effects of differences in absolute liking on intake. Likewise, since liking ratings decrease with repeated consumption (usually interpreted as a consequence of SSS), we also needed to control for changes across time. Hedonic contrast itself is then the product of the perceived difference in liking for two foods, and so requires sequential serving of foods varying in liking. In order to incorporate tests of palatability, SSS and hedonic contrast into a single test design, we examined intake when food was consumed in three different conditions. In each case, participants evaluated a sequence of four servings of snack foods. To examine simple palatability effects, one group consumed a liked version of these snacks (the Palatable condition) and a second a less flavoursome, less liked version (the Bland condition). Absolute intake in these two conditions allowed a direct replication of the well-known effects of palatability, while assessing intake across four consecutive servings of the same food allowed us to measure decreases in liking with repeated consumption, in line with SSS. To assess hedonic contrast, a critical third group consumed the same foods, but alternating between Palatable then Bland conditions, starting with Palatable. The logic here was that the initial experience of the more liked food would reduce liking for the first serving of the bland food compared to that experienced in the Bland condition (i.e. a negative hedonic contrast). Likewise, when participants then switched back to the palatable food (their third serving), the positive hedonic contrast they would experience was predicted to further enhance liking and so drive further intake. Thus,

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by alternating courses in this way we could assess effects of both positive and negative hedonic contrast and contrast these to simple effects of palatability and SSS, through the two control (Palatable and Bland) conditions. Mindful that hedonic contrast is affected by cuisine (Lahne, et al., 2017), we also used the same type of food throughout (potato crisps), and used a single sensory manipulation (level of added salt) to ensure intake was not confounded by macronutrient or other differences between the two test foods.

2.0 Methods

2.1 Design

The study used a mixed-participants design to contrast intake of four servings of a snack food (potato crisps), which were either all salted (Palatable condition), unsalted (Bland condition), or alternated between palatable and unpalatable foods (Contrast condition).

2.2 Participants

The study tested 96 female volunteers, mostly students at the University of Sussex, who were aged 19 – 34 years (mean 21.5, SD 2.1). Potential participants were recruited by a combination of flyers distributed around campus, postings on the School of Psychology volunteer web-list and by word of mouth. We focussed on female participants to simplify analyses, since past research would suggest that men would likely eat more than women (e.g. Harris, Bargh, & Brownell, 2009; Mittal, Stevenson, Oaten, & Miller, 2011). Those who had been diagnosed with an eating disorder, smoked more than 2 cigarettes per week, were pregnant or had a self-defined allergy or aversion to any of the test products were excluded. The study was advertised as examining individual differences in taste sensitivity to disguise the focus on intake.

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The research described in this report was reviewed and approved by the University of Sussex Science and Technology Research Ethics Committee (C-REC), protocol ER/Martin/11. All participants gave informed consent before participating and had the right to withdraw at any time during the study. The study was conducted in line with the standards laid out in the British Psychological Society's code of Ethics and Conduct.

2.3 Snack intake test

Since we needed two snack foods that differed in liking, achieved by subtle variations in flavour, but which were closely matched in all other respects, we selected potato crisps (known as potato chips in the US), using two commercial products. The food in the Palatable condition was a popular UK brand of salted crisps (Walkers Salted Crisps, Pepsico UK: 526kcal, 51.5 g carbohydrate, 31.9 g fat, 6.1 g protein per 100g, 1.4g NaCl), and the bland version was an unsalted version of the same product (Walkers "Salt and Shake Crisps", Pepsico UK: 533kcal, 52.2 g carbohydrate, 32.3 g fat, 6.2 g protein per 100g, 0.0g NaCl). This version is sold unsalted, but with a small sachet of salt that the consumer adds themselves. For our study, we simply discarded the additional salt to generate a bland crisp. All foods were served as 30.0g portions in white china snack bowls, and intake was calculated by weighing each bowl before and after consumption. Bowls were labelled with 3-digit codes (124, 489, 531, 882); the label used for each serving was counterbalanced within each condition.

2.4 Procedure

Testing was conducted either between 1000 and 1200 or 1500 and 1700 hours in testing cubicles at the Sussex Ingestive Behaviour Unit. Participants were randomly allocated to

test condition using a pre-test plan. Prior to testing, participants had been provided with an information sheet by email explaining the study, and requiring them to refrain from eating, and to drink only water, for the hour before testing. On the test day, after confirming their consent to participate, participants completed a short battery of computerised ratings of mood and appetite to allow level of hunger at the time of testing to be controlled for in analyses. Ratings were in the form 'How (word) do you feel?' where the adjectives rated were: clear-headed, drowsy, thirsty, lively, calm, full, nervous, relaxed, hunger and nauseous, presented as 100pt visual analogue scales (VAS) using Sussex Ingestion Pattern Monitor software (SIPM: described in Yeomans, 2000). On completion of these ratings, they were provided with a booklet of ratings to be made during the snack intake test, and were instructed that they were to rate the sensory characteristics ('taste') of each snack on five scales (all presented as 100mm VAS). The five ratings were presented in the order "How pleasant does this food taste?" (end-anchored "Extremely unpleasant", scored -50 and "Extremely pleasant", scored +50), and then how familiar, sweet, salty and savoury the snack was (all end-anchored "Not at all", scored 0 and "Extremely", scored 100). Pen and paper ratings were chosen so that the participants focussed on the snack rather than a computer screen to encourage consumption. They were then served the four snacks, one at a time in the appropriate order for their condition, with two minutes to complete the ratings and consume what they liked for each of the four servings. To further encourage consumption beyond simple tasting, they were told that all spare crisps would be disposed of so they could consume as much or as little as they wanted.

On completion of the snack test, participants completed two questionnaire measures which allowed us to ensure that there were no spurious group differences on measures known to

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affect short-term intake, and to allow exploratory analysis of how individual differences might impact on the experimental manipulations. The two questionnaires used were the original 51-item Three Factor Eating Questionnaire (TFEQ: Stunkard & Messick, 1985) and the Barratt Impulsiveness Scale (BIS-II: Patton, Stanford, & Barratt, 1995). The TFEQ was selected since both levels of restrained eating, as measured by the TFEQ restraint scale (TFEQR) and opportunistic eating (measured by the TFEQ disinhibition scale: TFEQD) have been shown widely to modify short-term intake in laboratory studies.

2.5 Data analysis

One participant (in the Bland condition) declined to be weighed and so their BMI data were missing, and the Qualtrics record for one participant (in the Contrast condition) had missing data for the BIS-II.

Intake of the sequential four bowls of snacks (within participant) were contrasted between conditions (between participants) using 2-way mixed ANOVA, followed up with 1-way between participants ANOVA for each of the four sequential servings, and for overall intake. In none of these analyses was Mauchly's test significant, indicating no evidence for violation of the assumption of sphericity. Where significant effects were found, these were followed up by specific contrasts between conditions within each serving: since we had predictions for the direction of most differences we used Tukey's LSD for these contrasts: for simplicity and brevity we only report p-values of these contrasts. To test whether overall intake in the Contrast condition could be explained as the sum of intake in the equivalent servings in the Palatable and Bland conditions, we calculated the sum of the first and third Palatable serving and second and fourth Bland serving, and then tested whether this differed from

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actual intake in the contrast condition using a *t*-test. Rated liking (the pleasantness rating) and saltiness of the four snack foods were also contrasted using 2-way mixed ANOVA (condition between and serving within participants), again followed up by analyses of each serving separately. Summary tables of key ANOVA outcomes are provided as supplementary files.

To test whether intake for each serving was predicted by actual liking ratings, we examined the correlations between intake and rated liking for each serving in each condition.

The full dataset can be found at: <https://figshare.com/s/79835af7a478dad76db8>. Data were analysed using IBM SPSS version 25 run on Macintosh computers.

3.0 Results

3.1 Participant overview

The three experimental groups were well matched on hunger at time of testing, age, BMI and key individual difference factors (Table 1), confirming there were no spurious group differences on these measures that might have confounded effects of the experimental manipulation.

3.2 Snack intake

As predicted, intake of the four bowls of snacks (Figure 1) varied depending on condition and bowl order [$F(6,279) = 28.76, p < 0.001, \eta^2 = 0.37$]. The key predictions of effects of palatability and SSS can be seen from intake in the Palatable and Bland conditions:

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participants consumed more in the Palatable than Bland condition, but intake decreased across repeated servings of the same food in line with SSS.

However, the key interest was intake in the Contrast condition. To understand this, we compared intake of each bowl between conditions for each of the four servings. For the first snack serving, intake in Contrast and Palatable conditions did not differ significantly, as would be expected as both were the same food, and both were significantly greater than in the Bland condition (both $p < 0.001$). For the second serving, significantly less was consumed in the Contrast than in the Bland ($p = 0.047$) or Palatable ($p = 0.002$) conditions, consistent with a negative-contrast effect, and intake in Palatable and Bland conditions no longer differed significantly ($p = 0.50$). For the third serving, intake in the Contrast condition was now significantly greater than in Palatable ($p < 0.001$) or Bland ($p < 0.001$) conditions, and again Palatable and Bland conditions did not differ significantly ($p = 0.27$), indicating that the intervening serving of the unsalted version stimulated intake of the salted version in the Contrast condition. For the final serving, significantly less was consumed in the Contrast than in the Bland ($p = 0.046$) or Palatable ($p = 0.007$) conditions, while intake in the Palatable and Bland conditions did not differ significantly ($p = 0.77$).

In addition, we looked at total snack intake, which varied significantly between conditions [$F(2,93) = 6.32$, $p = 0.003$, $\eta^2 = 0.12$]. Here, overall the most was consumed in the Contrast condition (36.9 ± 1.6 g), although this did not differ significantly from the Palatable condition (35.0 ± 2.6 g): significantly less was consumed in the Bland condition (26.6 ± 2.4 g: cf Contrast $p = 0.003$, cf Palatable $p = 0.021$). Finally, significantly more was consumed overall

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in the Contrast condition than in the sum of the equivalent Palatable and Bland servings (Contrast 36.9g versus 33.0g, $t(32) = 2.33$, $p=0.01$).

We also checked whether these differences in intake were still evident when controlling for hunger at the time of testing. Hunger was a significant predictor of overall intake [$F(1,92) = 4.90$, $p = 0.026$, $\eta^2 = 0.05$], and inclusion of hunger as a covariate increased the overall significance of condition [$F(1,92) = 7.27$, $p < 0.001$, $\eta^2 = 0.14$], confirming that condition differences were not indirectly driven by differences in baseline hunger. Hunger was not a significant covariate in analysis of individual servings, where the differences between conditions masked effects of appetitive state.

3.3 Snack hedonic and sensory ratings

Analysis of rated liking for the test foods confirmed that the flavour manipulation had the expected effect (Figure 2a). Overall analysis confirmed significant main effects of condition [$F(2,93) = 33.61$, $p < 0.001$, $\eta^2 = 0.42$], serving [$F(3,279) = 54.68$, $p < 0.001$, $\eta^2 = 0.37$], and the interaction of condition and serving [$F(6,279) = 23.85$, $p < 0.001$, $\eta^2 = 0.34$]. In the Palatable condition, the salted crisps were liked when first served (i.e. VAS pleasantness > 50), and liking then decreased with repeat exposure: the Bland crisps were mildly disliked at the start, and became more disliked over repeated servings. Comparisons by serving confirmed similar liking for the salted crisps in the Palatable and Contrast condition when first served, both significantly more pleasant than for the Bland crisps (both $p < 0.001$). Likewise, the unsalted crisps were equally disliked in the Bland and Contrast conditions for the second serving, and both were less liked than the salted crisps (Palatable condition, both $p < 0.001$).

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When served their third bowl, those in the Contrast condition re-experienced salty crisps having just consumed unsalted, and that clearly altered their evaluation. Here the rating of salted crisps was significantly higher in the Contrast than Palatable conditions ($p < 0.001$), and both ratings were higher than for the unsalted crisps in the Bland condition (both $p < 0.001$). While participants in the Contrast condition tended to rate their second serving of salted crisps as more pleasant than their first (28.5 cf 24.2), this difference was not significant ($t(31) = 1.42$, $p = 0.17$). When switched back to unsalted crisps for their final bowl, those in the Contrast condition rated these as more unpleasant than did those in the Bland condition who had been served four consecutive bowls of unsalted crisps ($p = 0.045$), while the salted crisps consumed in the Palatable condition remained significantly more pleasant (both $ps < 0.001$).

Since the key flavour manipulation was with saltiness, we also looked at salty ratings to confirm the experimental manipulation and also examine whether saltiness was affected in the Contrast condition. Overall analysis confirmed main effects of condition [$F(2,92) = 290.77$, $p < 0.001$, $\eta^2 = 0.86$], serving [$F(3,279) = 65.16$, $p < 0.001$, $\eta^2 = 0.41$], and the interaction of condition and serving [$F(6,279) = 52.07$, $p < 0.001$, $\eta^2 = 0.53$]. Saltiness ratings remained constant across servings at around 70pt on the VAS scale in the Palatable condition, and around 25pt in the Bland condition (Figure 2B). The interest here was whether the interweaving of salted and unsalted crisps in the Contrast condition would lead to changes in experience for the third and fourth servings. There was no evidence that the second experience of salted crisps in the Contrast condition was altered by the experience of unsalted crisps beforehand: rated saltiness in Contrast and Palatable conditions for the third serving did not differ significantly, and both were significantly more salty than the

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unsalted crisps (Bland condition, all p s<0.001). However, in the fourth serving the unsalted crisps rated by the Contrast group were significantly less salty than the same crisps experienced in the Bland condition ($p=0.045$), while the salted crisps were still rated as much saltier as expected (Palatable condition, both p <0.001).

3.4 The relationship between liking and intake.

Although average liking ratings confirmed that Bland and Palatable foods were liked differently, there was still considerable individual variation in liking and intake scores. However, when correlations were calculated for each serving in each condition (Table 2), only in four instances were these correlations significant: for both servings of salted crisps in the Contrast condition and the first two servings of salted crisps in the Palatable condition.

Liking ratings for the second serving of salted crisps in the Contrast condition were affected by the interceding experience of unsalted crisps. We therefore also asked whether individual differences in these contrast-induced liking changes predicted intake in the Contrast condition. First we calculated the change in liking for the salted crisps between the two servings: here the change in liking for the salted crisps predicted how much was consumed of the salted crisps in serving three ($r(32) = 0.40$, $p=0.023$). We also tested the effects of the difference in liking between the unsalted crisps (serving two) and salted crisps (serving three): this difference also predicted intake for serving 3 ($r(32) = 0.53$, $p=0.002$).

These two analyses both show that hedonic contrast predicted short-term intake.

3.5 Interactions with individual difference factors

To test for potential influences of individual difference factors on these data, initial analysis repeated the analysis of overall intake but including TFEQR, TFEQD or the overall score on the BIS as covariates: in no analysis was there any effect of the covariate or interaction between the covariate and the effect of condition. Likewise, intake in the Contrast condition did not correlate with TFEQR, TFEQD or BIStotal. Since these individual differences were not a key focus of the study, we did not explore this further.

4.0 Discussion

This study suggests that the impact of liking on intake in a multi-course snack is a dynamic process, with liking for each serving influenced by the preceding serving. Where the foods remain the same throughout, this process can be explained by SSS, with decreased liking across courses corresponding with decreased intake. Likewise, the effects of palatability superimpose on these SSS effects, with differences in liking at the start of the meal affecting overall intake, evidenced by greater overall intake in the Palatable than Bland conditions, in line with the widely accepted effects of palatability (Yeomans, 2007). However, these influences of liking become more complex where the food alternated between palatable and bland versions (the Contrast condition). Here, the effects of hedonic contrast altered liking in a predictable manner, and critically this altered liking then determined voluntary intake. Thus, these data both further demonstrated that hedonic contrast can influence intake and provided evidence that the altered intake could be explained by the contrast-induced change in liking.

In line with previous studies (e.g. Lahne, et al., 2017; Lahne & Zellner, 2015), the present study provided further evidence that the rated liking for one food was influenced by liking of

what was eaten immediately beforehand. The alternating procedure used in the Contrast condition evidenced both negative hedonic contrast through decreased liking for the Bland (unsalted) crisps after consuming the Palatable (salted) crisps (at both the second and fourth serving), and positive hedonic contrast, through increased liking for the Palatable crisps (third serving) after consuming the Bland crisps (second serving). What was striking was that overall liking for the Palatable crisps in the third serving in the Contrast condition was at least as strong as it had been for serving one, whereas the same crisps were rated as much less liked at this stage in the Palatable condition (Figure 2).

One possible explanation for this could be through dishabituation of SSS, based on the suggestion that SSS involves progressive hedonic habituation (Epstein, Temple, Roemmich, & Bouton, 2009). Accordingly, where intake of a food is interrupted by the experience of other novel stimuli (here the alternating crisp flavour) this is hypothesized to disrupt habituation to the hedonic-sensory characteristic of the ingested food, restoring the original level of liking (a process of dishabituation). The validity of the habituation model of SSS has, however, been questioned, with a number of studies designed to test that theory failing to find evidence of dishabituation (Havermans, 2012; Meillon, Thomas, Havermans, Pénicaud, & Brondel, 2013). Moreover, our finding of negative hedonic contrast cannot be readily explained as dishabituation: if intervening courses simply reset liking to its baseline value, as dishabituation posits, then the rated mild dislike for the unsalted crisps at the second and fourth courses should have been the same as the rated liking for unsalted crisps when first experienced in the Bland condition. Notably, liking for these crisps at the final serving was lower than for any serving in the Bland, contrary to predictions based on dishabituation of SSS. Overall, the dynamic changes in liking across the four courses in the Contrast condition

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cannot readily be explained by SSS alone, and the additional concept of hedonic contrast offers a plausible alternative.

What was clear in these data was that liking was a strong predictor of intake. This was evident in the overall difference in intake between Palatable and Bland conditions, which in turn replicates an extensive literature on simple hedonic effects on ingestion (Yeomans, 2007). More importantly, the change in liking induced by hedonic contrast also predicted intake. Thus, intake of salted crisps at the third serving was predicted by the change in liking for those crisps induced by the prior experience of the less liked unsalted crisps (positive hedonic contrast). Likewise, intake of the final bowl of unsalted crisps was predicted by the change in liking for those crisps by hedonic contrast with the preceding salted crisps (negative hedonic contrast). These findings therefore indicate that the effects of hedonic contrast on intake can be explained by the actual liking for the food being consumed at that moment, but that liking is in part derived by the experience of that food relative to the previously consumed item. This suggests a dynamic concept of palatability, where palatability is a hedonic evaluation of a food made in the context in which it is to be consumed.

As with any initial investigation, the current study has some limitations. In order to evaluate the effects of positive and negative hedonic contrast across multiple settings, intake at all four courses was ad libitum, and that raises the possibility that liking could be affected by satiation. For example, participants had consumed on average 32.9 g crisps prior to their fourth serving in the Contrast condition, compared with 20.4 g at that stage in the Bland condition. It could therefore be argued that their reduced liking for serving four was partly

because they were more satiated. But if satiety influenced liking, we would also have expected to see reduced liking for the salted crisps (serving three) in the Contrast condition, but here rated liking was similar to that for the first bowl, with no evidence for any satiety-induced decrease. While we recognise that ad libitum intake does complicate interpretation, the effects of satiety cannot explain the changes in liking and intake across courses in the Contrast condition. However, a follow-up study might look to control for this, possibly by having the initial serving as a fixed portion.

The study also focussed on a single food, potato crisps, and that could limit the extent to which findings are generalisable: it would be interesting to replicate these effects using foods varying in sweetness for example. SSS is also normally assessed by specifically measuring liking for an ingested food relative to non-ingested control foods: SSS is then evidenced by the relative decline in liking for consumed versus non-consumed items. The nature of testing in this study precluded the use of that approach, which could have been implemented in the Bland and Palatable conditions, but not the Contrast condition. Again, follow-up studies might want to find ways to incorporate traditional SSS tests into a hedonic contrast framework.

Our finding that hedonic contrast can enhance intake of a more liked food, and decrease intake of a less liked food, has some practical implications. It implies that where a meal consists of multiple items served at the same time, discrepancies in hedonic valance will be exaggerated, potentially leading to less of the least preferred items being consumed than if the same foods had been presented differently. Accordingly, hedonic contrast could, for example, negatively impact intake of vegetables served alongside more palatable

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components. Likewise, in multi-item meals, the hedonic valance of the first course is likely to impact liking for subsequent courses, in line with earlier findings (Lahne, et al., 2017; Lahne & Zellner, 2015), but where to date effects on intake have not been assessed. These suggestions could be explored in future research, particularly looking at how contrast effects may impact ingestion in groups known to be sensitive to sensory cues, including younger children and older adults.

In summary, this study contrasted how liking and intake of a multi-course snack was affected by relative liking for the consumed foods. The current data provided further evidence for hedonic contrast effects in liking for foods and demonstrated that these hedonic contrast effects impacted on voluntary intake, driven by actual liking at the point of consumption. These data suggest that hedonic contrast may be another driver of short-term intake and may act to promote overconsumption.

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488 **5.0 Author contributions**

489 MR Yeomans and J Morris designed the study. Data were collected by RM Armitage and MR
490 Yeomans. MR Yeomans analysed the data and prepared the draft MS which was reviewed
491 and updated by J Morris and RM Armitage.

492

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Table 1. Characteristics of the participants in the three experimental conditions

Measure	Condition			Statistical comparison
	Contrast	Palatable	Bland	
Age	21.5 ± 0.5	21.3 ± 0.3	21.7 ± 0.3	F(2,93) = 0.29, p=0.75
BMI	23.7 ± 0.7	22.9 ± 0.5	22.5 ± 0.4	F(2,92) = 0.60, p=0.55
Hunger at test	40.8 ± 5.6	49.6 ± 4.9	48.7 ± 4.5	F(2,93) = 0.96, p=0.39
TFEQR	7.8 ± 1.1	8.9 ± 1.0	9.6 ± 1.0	F(2,93) = 0.85, p=0.43
TFEQD	7.4 ± 0.6	7.1 ± 0.6	7.7 ± 0.6	F(2,93) = 0.22, p=0.81
BIStotal	2.2 ± 0.1	2.2 ± 0.1	2.3 ± 0.1	F(2,92) = 0.45, p=0.64

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593 Table 2. Correlations (Pearsons r) between rated liking and intake for each serving in each
594 condition.

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Condition	Serving			
	1	2	3	4
Contrast	0.45*	0.16	0.59*	-0.22
Palatable	0.51*	0.52*	0.26	0.32
Bland	0.20	0.02	0.28	0.28

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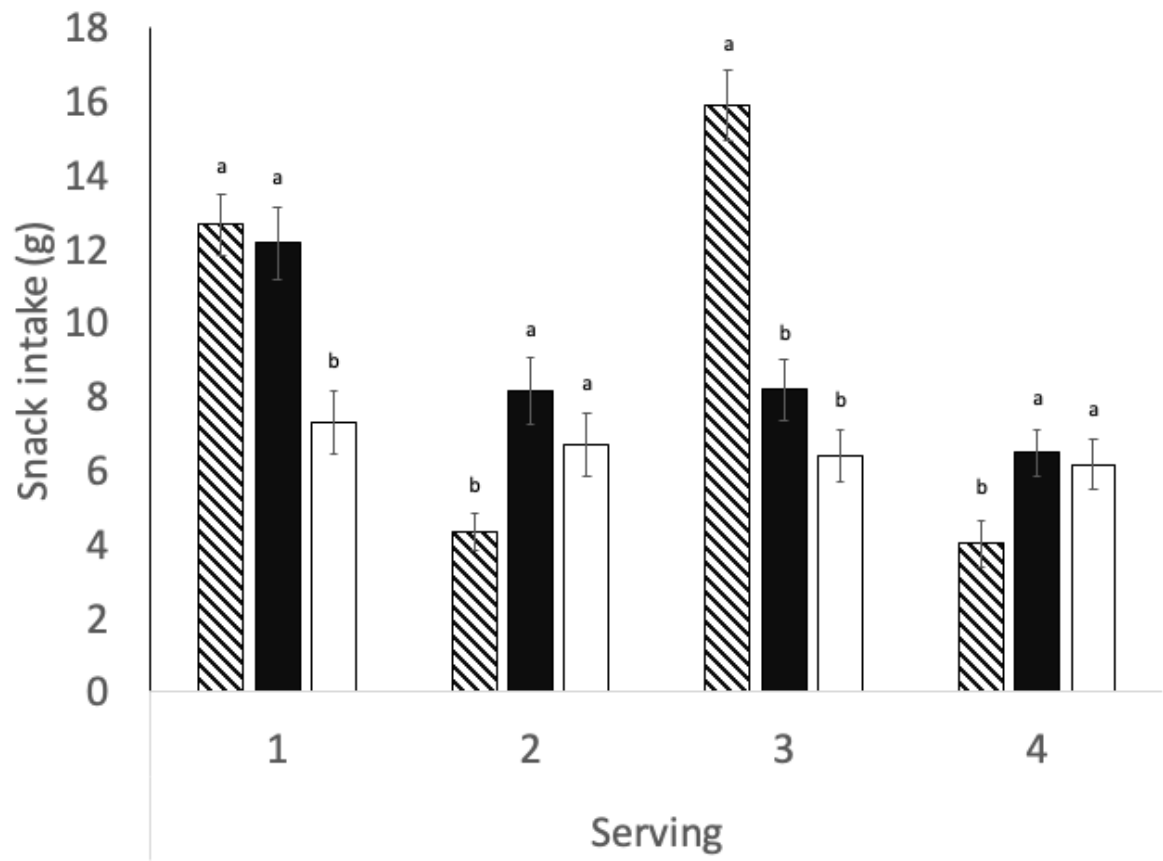
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Figure Legends

Figure 1: Intake of the test snack foods in the four sequential servings in the Contrast (▨), where participants consumed the palatable version at servings 1 and 3 and bland at servings 2 and 4, Palatable (■) and Bland (□) conditions. For each serving, columns marked with different letters differ significantly ($p < 0.05$ or less).

Figure 2: Ratings of (A) overall pleasantness and (B) saltiness of the test snack foods in the four sequential servings in the Contrast (▨), Palatable (■) and Bland (□) conditions. For each serving, columns marked with different letters differ significantly ($p < 0.05$ or less).

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